DECLARATION FOR TRANSLATION

I, Jun Ishida, a Patent Attorney, of 1-34-12 Kichijoji-Honcho, Musashino-shi, Tokyo, Japan, do solemnly and sincerely declare that I well understand the Japanese and English languages and that the attached English version is a full, true and faithful translation made by me

this 4th day of December, 2002

of the Japanese Patent Application of No. Hei 8-43675

entitled "LIQUID CRYSTAL DISPLAY"

In testimony thereof, I have herein set my name and seal

this 4th day of December, 2002

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[Title of the Invention] LIQUID CRYSTAL DISPLAY

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[Document] Specification

[Title of the Invention] LIQUID CRYSTAL DISPLAY

[What Is Claimed Is]

[Claim 1] A liquid crystal display comprising:

pixel electrodes arranged in a matrix on a first substrate for driving a liquid crystal;

a thin film transistor having a source electrode connected to said pixel electrodes;

a gate line connected to a gate electrode of said thin film transistor;

a drain line connected to a drain electrode of said thin film transistor; and

a common electrode for driving liquid crystal formed on a second substrate which is disposed opposing the first substrate having a liquid crystal layer in between,

wherein

the pixel electrodes are formed on an inter-layer insulation film which is formed to cover the thin film transistor, the gate line, and the drain line; and

an orientation control window of a predetermined pattern on which no electrodes are formed is disposed in a region opposing each one of the corresponding pixel electrodes.

[Claim 2] A liquid crystal display as defined in claim 1, wherein the inter-layer insulation film has a thickness of 0.5 μm or more.

[Claim 3] A liquid crystal display as defined in claim 1, wherein the inter-layer insulation film has a thickness of 1μm or more.

[Claim 4] A liquid crystal display as defined in any one of claims 1 to 3, wherein each of the pixel electrodes is arranged in a region enclosed by the gate line and the drain line so as to overlap, via the inter-layer insulation film, with the gate line or/and the drain line.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a liquid crystal display (LCD) utilizing the electro-optical anisotropy of liquid crystal, and in particular, to an LCD for achieving a high aperture ratio and a wide viewing angle.

[0002]

[Description of the Prior Art]

The LCD is advantageous in that it is small and light-weight, and has low power consumption. It is thus put into practical use in such fields as in OA and AV equipment. In particular, the active matrix type which uses a thin film transistor (TFT) for the switching element can, in principle, perform static drive of 100% duty ratio in a multiplexed manner, and is used for large screen, animation displays.

[0003]

Figs. 13 and 14 show the structure of a unit pixel for a conventional LCD; Fig. 13 is a plan view, and Fig. 14 is a cross-sectional view along the line C-C in Fig. 13. On a substrate 100 made of glass, etc., are provided a gate electrode 101 made of Cr, etc., and a gate line 102 for integrally connecting the gate electrodes 101 aligned in the same row direction. A gate

insulation film 103 made of Si_3N_4, etc., is formed so as to cover the entire surface of them. On the gate insulation film 103, there is formed an island-shaped amorphous silicon (a-Si) layer 104 in a region corresponding to the gate electrode 101 so as to act as an operating layer for the TFT. Amorphous silicon regions doped with impurities, are formed at both ends of the a-Si layer 104 to create (N^+a-Si) layers 106 to act as contact layers. Between the a-Si layer 104 and the (N^+a-Si) layers 106, an etching stopper 105 made of Si_3N_4 is formed as required for structural reasons. Further, on the (N^+a-Si) layers 106, there are respectively disposed a source electrode 107 and a drain electrode 108 both made of refractory metal, such as Al/Si, etc. In other regions on the gate insulation film 103, a pixel electrode 110 made of Indium Tin Oxide (ITO) which is transparent and conductive is fomred. Further, a drain line 109 is also provided for integrally connecting the drain electrodes 108 aligned in the same column direction. An alignment layer 111 made of a polymer film such as polyimide is formed so as to cover all of the components mentioned above. The alignment layer 111 is subjected to a predetermined rubbing treatment for controlling the initial orientation of liquid crystal molecules. On another glass substrate 120 disposed opposing the substrate 100 having a liquid crystal layer 130 in between, a common electrode 121 made of ITO is formed on the entire surface of the glass substrate 120. The common electrode 121 is covered by an alignment layer 122 made of polyimide, etc., which is subjected to a rubbing treatment.

[0004]

Liquid crystal is a nematic phase having, for instance,

positive anisotropy of dielectric constant, and specifically a twist nematic (TN) mode is employed in which orientation vectors are twisted by 90 degrees between the top and bottom substrates 100, 120. A polarizing plate (not shown) is generally provided outside each of the substrates 100/120 such that, in the TN mode, a polarizing axis thereof matches a rubbing direction of the alignment layer 111/122 on the corresponding substrate 100/120. Thus, when no voltage is applied, linearly polarized light incoming through one of the polarizing plates revolves in the liquid crystal layer 130 along the twisted orientation of the liquid crystal molecules, until it comes out from the other polarizing plate. The LCD then displays white. On the other hand, a predetermined voltage is applied between the pixel electrode 110 and the common electrode 121, and an electric field is formed in the liquid crystal layer 130, so that liquid crystal molecules change their orientation due to their dielectric constant anisotropy such that they become parallel to the electric field. As a result, the twisted orientation of the liquid crystal molecules is destroyed, and incoming linearly polarized light is thus forced to stop revolving in the liquid crystal layer 130. Then, only a reduced amount of light comes out from the other polarizing plate, resulting in a gradual change of a displayed color to black. The above mode in which an LCD displays white with no voltage applied and black with voltage applied is referred to as a normally-white mode, which is mainly employed for TN cells.

[0005]

Another example is a DAP (deformation of vertically aligned phases)-type LCD which uses a nematic phase having a negative

anisotropy of dielectric constant for an LCD, and a vertical alignment layer for the orientation films 111, 122. A DAP-type LCD, which is one example of those employing electrically controlled birefringence (ECB), utilizes a difference in a refractive index between a long axis and a short axis of liquid crystal molecules, i.e., birefringence, for controlling transmission and displayed colors. For this type, a polarizing plate is formed in a crossed Nicols arrangement outside each of the substrates 100/120. When voltage is applied, linearly polarized light introduced via one of the polarizing plates is converted into elliptically polarized light via birefringence in liquid crystal layer 130. The retardation of this elliptically polarized light, i.e., the difference in phase speed between an ordinary and an extraordinary ray, is controlled according to the strength of electric fields generated in liquid crystal layer 130 to cause colored light with a desired transmission to come out from the other polarizing plate.

[0006]

[Problems to be Solved by the Invention]

As described above, an LCD obtains a desired transmission or displays desired hues by applying a desired voltage to liquid crystal which is sandwiched by a pair of substrates having predetermined electrodes formed thereon to control light revolution or birefringence in the liquid crystal. In other words, a retardation amount is controlled by changing the orientation of liquid crystal molecules, such that, in a TN mode, the strength of transmitted light can be controlled. In an ECB mode, hue separation is also achieved by controlling the strength of

transmitted light, which depends on wavelength. A retardation amount depends on an angle formed by a long axis of a liquid crystal molecule and the direction of an electric field generated in the liquid crystal. Therefore, even if this angle is primarily controlled by adjusting electric field strength, a relative retardation amount will vary depending on an angle at which an observer views the LCD, i.e., a viewing angle. As viewing angle varies, the strength or the hues of transmitted light also changes, which results in a so-called view angle dependency problem.

[0007].

[Means for Solving the Problems]

This invention has been conceived to overcome the above problems.

According to one aspect of the present invention, there is provided a liquid crystal display comprising pixel electrodes arranged in a matrix on a first substrate for driving a liquid crystal; a thin film transistor having a source electrode connected to said pixel electrodes; a gate line connected to a gate electrode of said thin film transistor; a drain line connected to a drain electrode of said thin film transistor; and a common electrode for driving liquid crystal mounted on a second substrate which is disposed opposing the first substrate having a liquid crystal layer in between, wherein the pixel electrodes are formed on an inter-layer insulation film which is formed to cover the thin film transistor, the gate line, and the drain line; and an orientation control window of a predetermined pattern on which no electrodes are formed is disposed in a region opposing each one of the corresponding pixel electrodes.

[0008]

With this arrangement, a liquid crystal layer is situated away from a TFT and associated electrode lines. This distance between the former and the latter results in protecting an electric field sloped around the edges of the orientation control window and an electric field sloped around the edges of a pixel electrode against the influence of electric fields generated by each electrode line of the TFT. Namely, the orientation of liquid crystal molecules is prevented from being affected by the electric fields generated by each electrode line of the TFT. Then, the orientation of liquid crystal molecules can be controlled secondarily in a preferable manner through these sloped electric fields. To be more specific, variation in a retardation amount for the entire pixel can be suppressed in a structure which has been designed such that increase or decrease of a retardation amount at respective points inside a pixel is offset despite varied viewing angle. This structure can be achieved, utilizing the fact that the horizontal orientation of liquid crystal molecules in a pixel is determined according to the shape of the orientation control window.

[0009]

In particular, an inter-layer insulation film is formed to have a thickness of 0.5μm, preferably 1μm or more.

Specifically, in normal driving for an LCD, with an inter-layer insulation film having a thickness of at least 0.5μm, preferably 1μm or more for separating a TFT and associated electrode lines thereof from the pixel electrodes, the TFT and associated electrode lines do not affect a liquid crystal layer through electric fields. Then, the orientation of liquid crystal molecules can be

effectively secondarily controlled through sloped electric fields generated in the liquid crystal layer around the edges of an orientation control window and a pixel electrode.

[0010]

In particular, the pixel electrode is formed in a region defined by the gate and drain lines, overlapping, via the inter-layer insulation film, with the gate line and/or the drain line.

That is, with an inter-layer insulation film, a pixel electrode is situated in a layer different from that of gate and drain lines, having a sufficient interval between them. This allows the pixel electrode to be disposed overlapping with the gate and drain lines so that a larger display region and an increased aperture ratio can be secured.

[0011]

[Embodiments]

Figs. 1 and 2 show the structure of a unit pixel for an LCD according to a first embodiment of the present invention. Fig. 1 is a plan view and Fig. 2 is a cross-sectional view along the line A-A in Fig. 1. On a transparent substrate 10 made of glass, etc., a conductive film made of Cr, etc., is formed in a predetermined shaped to have a thickness of 1500Å by means of etching using photo-lithography, whereby a gate electrode 11 and a gate line 12 are constituted. The gate line 12 integrally connects the gate electrodes 11 in the same row. Covering the whole surface of the substrate 10 on which the gate electrode 11 and the gate line 12 are formed, a Si_3N_4 or SiO_2 layer is formed to have a thickness of 2000Å to 4000Å by means of CVD to thereby

constitute a gate insulation film 13.

[0012]

On the gate insulation film 13, an amorphous silicon or a-Si layer 14 is formed in a region corresponding to the gate electrode 11, so that it will act as an operating layer for the TFT. Amorphous Si regions doped with impurities are formed at both ends of the a-Si layer 14 so as to obtain ohmic characteristics, forming (N^+a-Si) layers 16. Between the a-Si layer 14 and the (N^+a-Si) layers 16, an etching stopper 15 made of (Si_3N_4) is formed.

[0013]

These layers of the a-Si layer 14, the (N^+a-Si) layer 16, and the etching stopper 15 are formed as follows. After the gate insulation film 13 has been formed, an a-Si layer and a Si_3N_4 layer are successively formed thereupon in this order by means of CVD. The obtained Si_3N_4 layer is then etched to form an etching stopper 15. Subsequently, after a (N^+a-Si) layer has been formed by means of CVD on the layers already formed, the a-Si 14 and (N^+a-Si) layers 16 are collectively etched into the same shape, namely, the island-shape of a TFT.

[0014]

Then, Al/Si is sputtered onto the layers formed thus far until it has an accumulated thickness of 700/1000Å. The obtained Al/Si layer is etched to form a source electrode 17 and a drain electrode 18, which are connected to the respective (N^+a-Si) layers 16. With the above, a TFT is constituted. Further, a drain line 19 is provided, intersecting the gate line 12, for integrally connecting the drain electrodes 18 in the same column.

[0015]

Over the whole surface covering the gate insulating film 13 on which these TFT and associated electrode lines are formed, a Si_3N_4 or SiO_2 film having a thickness of 1 to 5 μm is accumulated to form an inter-layer insulation film 20.

Further, a region enclosed by the gate lines 12 and the drain lines 19 on the inter-layer insulation film 20 is sputtered with ITO, and the ITO is then etched to form a pixel electrode 22. The pixel electrode 22 is connected to the source electrode 17 through a contact hole 21 which has been formed in the inter-layer insulating film 20 by etching prior to provision of the ITO. The pixel electrode 22 extends above the gate line 11, the drain line 19 and the TFT, having the inter-layer insulation film 20 between them.

[0016]

Covering the inter-layer insulation film 20 and the pixel electrode 22, an alignment film 22 made of polyimide, etc., is formed. Rubbing the surface of the alignment film 22 in the direction from upper right to lower left in Fig. 1 results in controlling liquid crystal molecules to have uniform initial orientation.

An opposing substrate 30 is disposed so as to face the TFT substrate 10 having the above structure, with a liquid crystal layer 40 being formed between them. On the surface of the opposing substrate facing the TFT substrate, ITO is provided to cover almost all the surface to form a common electrode 31. A band region having no electrode formed therein is made by means of etching the common electrode 31 in the region corresponding to the pixel electrode 22. This band region, constituting an orientation control window

32, extends in the diagonal direction of the pixel. As with the TFT substrate 10 side, the whole surface of the opposing substrate 10 having the common electrode 31 formed thereon is covered by an alignment film 33 made of polyimide, etc. The surface of the film 33 is also rubbed in the direction from bottom right to upper left of Fig. 1 to impart uniform initial orientation to liquid crystal molecules.

[0017]

Particularly in the TN mode, rubbing directions for the alignment films 23, 33 are defined so as to be orthogonal to each other, so that liquid crystal molecules are arranged twisted by 90 degrees between the two films 23, 33. The outsides of both substrates 10, 30 are covered by polarizing plates (not shown) such that polarizing light axes thereof match with respective rubbing directions.

[0018]

In a pixel cell in which the orientation control window 32 is formed traversing the pixel from upper right to lower left as shown in Fig. 1, the rubbing direction for the alignment film 33 on the opposing substrate side is defined as traversing the pixel from upper left to lower right, i.e., orthogonal to the extended line of the alignment control window 32. With this arrangement, when voltage is applied and an electric field is thus generated in a sloped direction around the edges of orientation control window 32, liquid crystal molecules nearby will rise, moving in the shortest distance, such that one end of their long axes becomes closer to the electric field direction. In other words, respective liquid crystal molecules are inclined towards the

nearest edge of the opposing edges of the window 32. Liquid crystal molecules are resultantly inclined in the opposite directions between both sides of the window 32.

[0019]

On the TFT substrate 10 side, electric fields are generated in the sloped direction around the edges of the pixel electrode 22. Due to these electric fields, liquid crystal molecules in the neighborhood of the respective edges of the pixel electrode 22 rise such that their outer ends are lifted. This movement results in molecules having opposite ends lifted between two edges in the upstream side and the downstream side of the rubbing direction. At the opposing substrate 30 side, as described above, opposite ends of LC molecules are made to rise between both opposing sides of the orientation control window 32. Thus, horizontal orientation of liquid crystal molecules becomes opposite between the two sides with the alignment control window 32 as a boundary, so that pixel dividing is achieved. This enables a wide viewing angle. At this time, regions where liquid crystal molecules rise against a pre-tilt angle imparted through rubbing are referred to as a reverse tilt domain.

[0020]

As described above, in the structure shown in Figs. 1 and 2, the orientation of liquid crystal molecules is secondarily controlled through electric fields generated in the sloped direction around the edges of the pixel electrode 22 and the alignment control window 32, so that pixel dividing is achieved. In particular, these electric fields are not disturbed by a voltage difference between the pixel electrode 22 and the gate electrode,

the drain electrode, and associated lines 11, 12, 18, 19 in a structure wherein the pixel electrode 22 is located in an upper layer of the TFT having an inter-layer in between, in other words, the former is kept away from the latter. As a result, preferable pixel dividing can be achieved.

[0021]

As will be understood from the above, in the structure shown in Figs. 1 and 2, the influence on the state of display of an electrode and associated lines 11, 12, 18, 19 is determined according to the thickness of the inter-layer insulation film 20. Figs. 3 to 5 show the results of electric field simulation as to the orientation of liquid crystal molecules when the thickness of the inter-layer insulation film 20 is varied. The drawings show equipotential lines by dotted lines, and the orientation of liquid crystal molecules which depends on the shape formed by an equipotential line by a solid thick line, respectively in cases where the inter-layer distance between the gate line (GATE) and the pixel electrodes (PX1, PX2) which are formed to sandwich the gate line is set to 1μm, 3μm, and 5μm, respectively. Pixel electrode (PX1) represents a pixel having an end in the vicinity of which molecules present normal orientation; pixel electrode (PX2) represents a pixel having an end in the vicinity of which a reverse tilt domain is caused.

[0022]

Referring to Fig. 3, in the case of a relatively small inter-layer distance, i.e., 1μm , a reverse tilt domain (RT) is caused on the pixel electrode (PX2) side, and the orientation (DIR) of molecules is disturbed on the pixel electrode (PX1) side. This

may be due to a large negative gate voltage, and thus there is an affect of an electric field generated by the gate line (GATE).

Referring to Fig.4, although a reverse tilt domain (RT) is still observed on the pixel electrode (PX2) side, the orientation is less disturbed on the pixel electrode (PX1) side. This may be because an electric field generated by the gate line (GATE) has less affect as the inter-layer distance grows larger, such as 3 μm in this example.

[0023]

Referring to Fig. 5, in which the inter-layer distance is further widened to 5μm, the orientation (DIR) is further less disturbed on the pixel electrode (PX1) side, though a small reverse-tilt domain (RT) is still observed on the pixel electrode (PX2) side.

Fig. 6 shows, corresponding to Figs. 3 to 5, a relationship between transmission and positions of the edges of pixel electrodes when the inter-layer distance between the pixel electrodes (PX1, PX2) and the gate line (GATE) is 1μm, 3μm, or 5μm. With regard to a cell which is covered by a polarizing plate arranged in a crossed Nicols manner, the vertical axis in the drawing indicates transmission up to 0.5. The horizontal axis indicates, in a structure in which a gate line (GATE) of 10μm wide overlaps pixel electrodes (PX1, PX2) at respective ends by 3μm, positional relationship with regard to the direction orthogonal to the gate line (GATE). According to this drawing, in the case of 1μm, transmission peaks within regions corresponding to the pixel electrodes (PX1, PX2). That is, a boundary between normal and reverse tile regions is formed in these corresponding regions, so that light goes through the liquid crystal. In the case of 3

μm, transmission peaks in a region corresponding to the pixel electrode (PX2) at a point slightly further out than that in the case of 1μm, while no peak is observed for pixel electrode (PX1). In the case of 5μm , transmission peaks in a vicinity of a region at the edge of the pixel electrode (PX1). This region, however, is overlapped with the gate line (GATE), and the state of the display is thus not affected. In the region of the pixel electrode (PX2), on the other hand, transmission peaks at positions further out than in cases of 1μm and 3μm.

[0024]

Similarly to Figs. 3 to 5, Figs. 7 to 9 show simulation results obtained when an inter-layer distance between a drain line (DRAIN) and pixel electrodes (PX1, PX2) formed to sandwich the drain line is changed to be 1μm, 3μm, or 5μm, respectively. In the drawings, equipotential lines for respective cases are shown by dotted lines and the orientation of liquid crystal molecules which depends on the shape formed by the equipotential lines are shown by solid dashes. Pixel electrode (PX1) represents a pixel having an end in the vicinity of which molecules present normal orientation; pixel electrode (PX2) is a pixel having an end in the vicinity of which a reverse tilt domain is caused. Referring to Fig. 7, a reverse tilt domain (RT) is caused in the region corresponding to the pixel electrode (PX2) due to the influence of an electric field generated by the drain line (DRAIN). However, the orientation (DIR) is not significantly disturbed in the region for the pixel electrode (PX1) compared to the gate side, since the liquid crystal layer is less affected by a drain voltage with an effective value smaller than that of a gate voltage.

[0025]

Referring to Fig. 8, a reverse tilt domain (RT) becomes smaller in the region for the pixel electrode (PX2). The orientation (DIR) is not disturbed at all in the region for the pixel electrode (PX1). Referring to Fig. 9, neither reverse tilt domain nor disturbance in orientation is recognized in the regions for the pixel electrodes (PX1, PX2).

Fig. 10 shows, as with Fig. 6, transmission of a liquid crystal cell at points along the edges of the pixel electrodes (PX1, PX2) and the drain line (DRAIN), when an inter-layer distance is 1 μm, 3μm, and 5μm. The vertical axis indicates transmission while the horizontal axis indicates positional relationship viewed in the direction vertical to the drain line (DRAIN). For 1μm, transmission peaks in a region corresponding to the pixel electrode (PX2), most of which overlaps the drain line (DRAIN). For 3μm and 5μm, the region where a peak is observed on the pixel electrode (PX2) side completely overlaps with the drain line (DRAIN), and the state of display is thus not affected at all. On the pixel electrode (PX1) side, a position for peak transmission completely overlaps the drain line (DRAIN), and the state of display is thus not adversely affected.

[0026]

From the above observations, it may be concluded that by providing the inter-layer insulation film 20 of 1μm or more thick such that a distance between the pixel electrode 22 and the gate electrode and associated lines 11, 12 can be kept sufficiently large, particularly on the gate line side, liquid crystal molecules can be protected against orientation disturbance due to the

influence of a gate voltage, thereby securing a normal tilt region, and also, orientation control can be effectively performed around the edges of the pixel electrode 22 through a diagonal electric field, thereby leaving a reverse tile region. Therefore, when the orientation control window 32 is formed in the common electrode 31, as shown in Figs. 1 and 2, and electric fields in the sloped direction are generated also thereabout, a reverse tilt domain is formed so as to extend to the orientation control window 32 in cooperation between controls around the edges of the pixel electrode 22 on the gate line 12 side, and those inside a pixel region around the orientation control window 32. As a result, the orientation of liquid crystal molecules differs between the upper and lower sides of the orientation control window 32. As described above, the pixel electrode and the TFT and associated electrode lines, when being separated in the direction of the film thickness, allow effective orientation control around the edges of the pixel electrode. As a result, the orientation of liquid crystal molecules along the edges of a pixel electrode which are perpendicular to the average of the directions in which respective molecules are aligned can be easily controlled. Further, orientation control effected from both edges of the pixel electrode is gradually taken over by controls effective around the orientation control window, as the window goes into the inner side of a pixel cell, until the boundary of different orientation is finally defined on the orientation control window. In this way, preferable pixel dividing is achieved.

[0027]

Further, in the above structure, the pixel electrode 22 is formed

to extend to the gate electrode 11, the drain electrode 18, and associated lines 12, 19. This structure makes if possible to secure a maximum display region within a region defined by the edges of the respective electrodes and associated lines 11, 12, 18, 19, thereby significantly increasing an aperture ratio. A long inter-layer distance between the pixel electrode 22 and the gate and drain lines 11, 19 allows the pixel electrode 22 to extend to those lines while the electric field in the liquid crystal layer is not affected by the electric fields generated by those lines. Actual experimental results obtained showed a greater than 10% improvement in aperture ratio compared to the prior art structure.

[0028]

Figs. 11 and 12 show a structure of a unit pixel for an LCD according to a second embodiment of the present invention. Fig. 11 is a plan view, and Fig. 12 is a cross-sectional view along the line B-B in Fig. 11. Electrode arrangement is the same as that in the first embodiment shown in Figs. 1 and 2. That is, a TFT comprises a substrate 50, a gate electrode 51, a gate insulation film 53, an a-Si layer 54, an etching stopper 55, an (N^{+}a-Si) layer 56, and a source and drain electrode 57, 58, which are layered on the substrate 50 in that order. Further, gate and drain electrodes 51, 58 are formed integral to respective gate and drain lines 52, 59. On an inter-layer insulation film 60 formed so as to cover the TFT and associated respective electrode lines, a pixel electrode 62 is formed and is connected to the source electrode 57 via a contact hole 61. On a substrate 70 provided so as to face the TFT substrate with a liquid crystal layer 80 therebetween, a common electrode 71 and an orientation control window 72 formed

within the common electrode 71 are provided to constitute an opposing substrate. In this example, an ECB mode is employed in which liquid crystal is a nematic phase having negative dielectric constant anisotropy, and vertical alignment layers 63, 73 are formed on the surfaces of respective substrates. The orientation control window 72 is formed in a shape of letter X, substantially along diagonal lines of the pixel.

[0029]

Based on a similar analysis as that made for the first embodiment, this embodiment is characterized by application of an inter-layer insulation film 60 having a thickness of at least 1μm or more. Separated by this film 60, the pixel electrode 62 is positioned away from the TFT and associated electrode lines, having a sufficient distance in between. The orientation of liquid crystal molecules is less affected by the influence of electric fields generated by the TFT and associated lines, and therefore less disturbed. As a result, orientation control can be effectively performed around the edges of the pixel electrode 62 and the orientation control window 72. More specifically, the horizontal orientations of liquid crystal molecules are designated in the regions along the edges of respective pixels through sloped electric fields generated thereabout, and this designation is gradually made through electric fields generated around orientation control window 72 as it goes into an inner side of the pixel until a boundary of different orientation is fixedly defined on the orientation control window 72. As a result, constant and preferable pixel dividing over the entire pixel is achieved, which enables a wider angle of visibility.

[0030]

[Advantageous Result]

As will be clearly understood from the above description, the pixel electrode for driving a liquid crystal is disposed away from the TFT and the associated electrode lines which drive the pixel electrode, such that the orientation of liquid crystal molecules is not affected by electric fields generated from these lines to thereby suppress orientation disturbance. Accordingly, when the orientation of liquid crystal molecules is secondarily controlled through electrical fields generated in the sloped direction around the edges of the pixel electrode and the orientation control on the common electrode side to achieve pixel dividing, it is possible to keep these diagonal electric fields free from disturbance and to thus achieve effective controls around the edges of the pixel electrode and the orientation control window. Therefore, preferable pixel dividing and a wider angle of visibility are realized.

[Brief Description of the Drawings]

[Figure 1] Plan view showing the structure of a unit pixel for an LCD according to a first embodiment of the present invention

[Figure 2] Cross-sectional view along the line A-A in Fig. 1

[Figure 3] Cross-sectional view showing equipotential lines and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 4] Cross-sectional view showing equipotential lines and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 5] Cross-sectional view showing equipotential lines

and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 6] Diagram showing transmission at points along the edges of pixels

[Figure 7] Cross-sectional view showing equipotential lines and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 8] Cross-sectional view showing equipotential lines and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 9] Cross-sectional view showing equipotential lines and orientation of liquid crystal molecules in a liquid crystal cell

[Figure 10] Diagram showing transmission at points along the edges of pixels

[Figure 11] Plan view showing the structure of a unit pixel for an LCD according to a second embodiment of the present invention

[Figure 12] Cross-sectional view along the line B-B in Fig. 11

[Figure 13] Plan view showing the structure of a unit pixel for a prior art LCD

[Figure 14] Cross-sectional view along the line C-C in Fig. 13

[Legend]

10, 20, 50, 70	substrate
11, 51	gate electrode
12, 52	gate line
13, 53	gate insulating film

14, 54	a-Si layer
15, 55	etching stopper
16, 56	N^+a-Si layer
17, 57	source electrode
18, 58	drain electrode
19, 59	drain line
20, 60	inter-layer insulating film
21, 61	contact hole
22, 62	pixel electrode
23, 33, 63, 73	alignment film
31, 71	common electrode
32, 72	orientation control window
40, 80	liquid crystal layer

[Document]Abstract

[Summary]

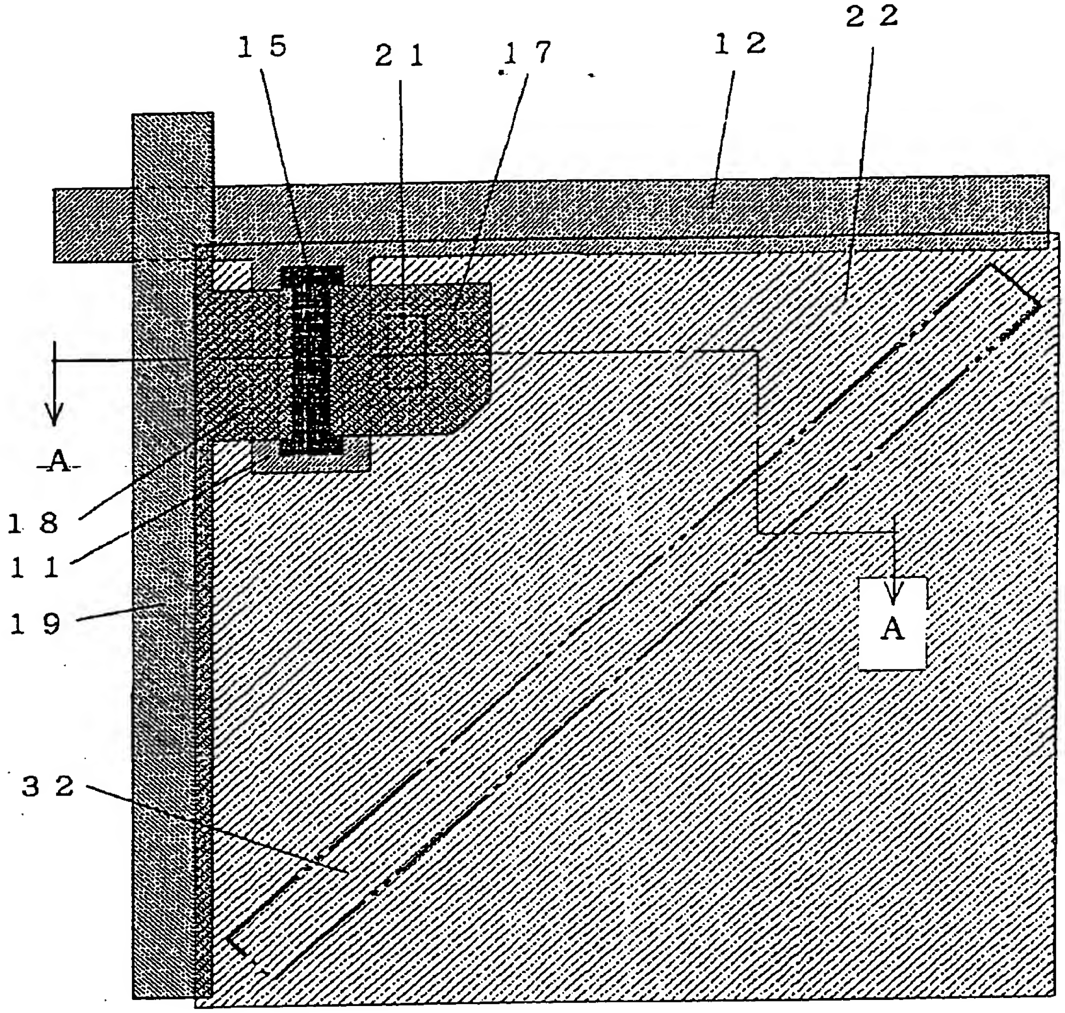
[Object] To prevent orientation disturbance of liquid crystal molecules due to the influence of electric fields generated by a TFT and associated lines, to thereby obtain preferable pixel dividing and a wider range of visibility.

[Solution] A TFT is provided by forming, on a substrate (10), a gate electrode (11), a gate insulation film (13), an a-Si layer (14), an etching stopper (15), an (N^+a-Si) layer (16), and a source and a drain electrode (17, 18) in this sequence. Covering this TFT, an inter-layer insulation film (20) is formed, on which a pixel electrode (22) is further formed. In a common electrode (31), there is formed an orientation control window (32) where no electrodes are situated. With this arrangement, it is possible to prevent the orientation of liquid crystal molecules from being disturbed due to the influence of electric fields generated by the gate electrode (11), the drain electrode (18), or their respective associated lines. As a result, the orientation of liquid crystal molecules is effectively controlled through electric fields generated in the sloped direction around the edges of the pixel electrode (22) and the orientation control window (32), thereby obtaining preferable pixel dividing and a wider range of visibility.

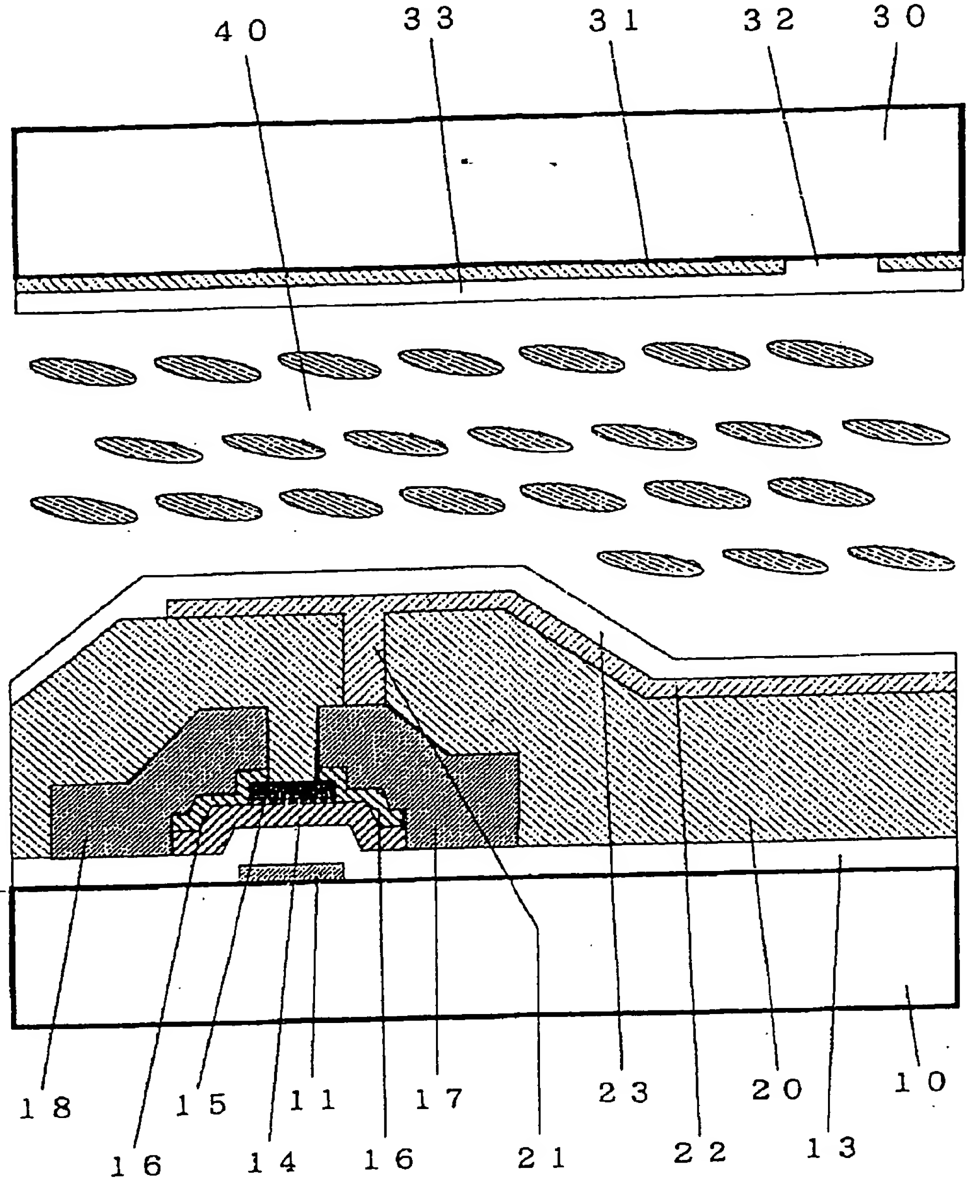
[Reference Drawing] Figure 2

[Document] Drawings

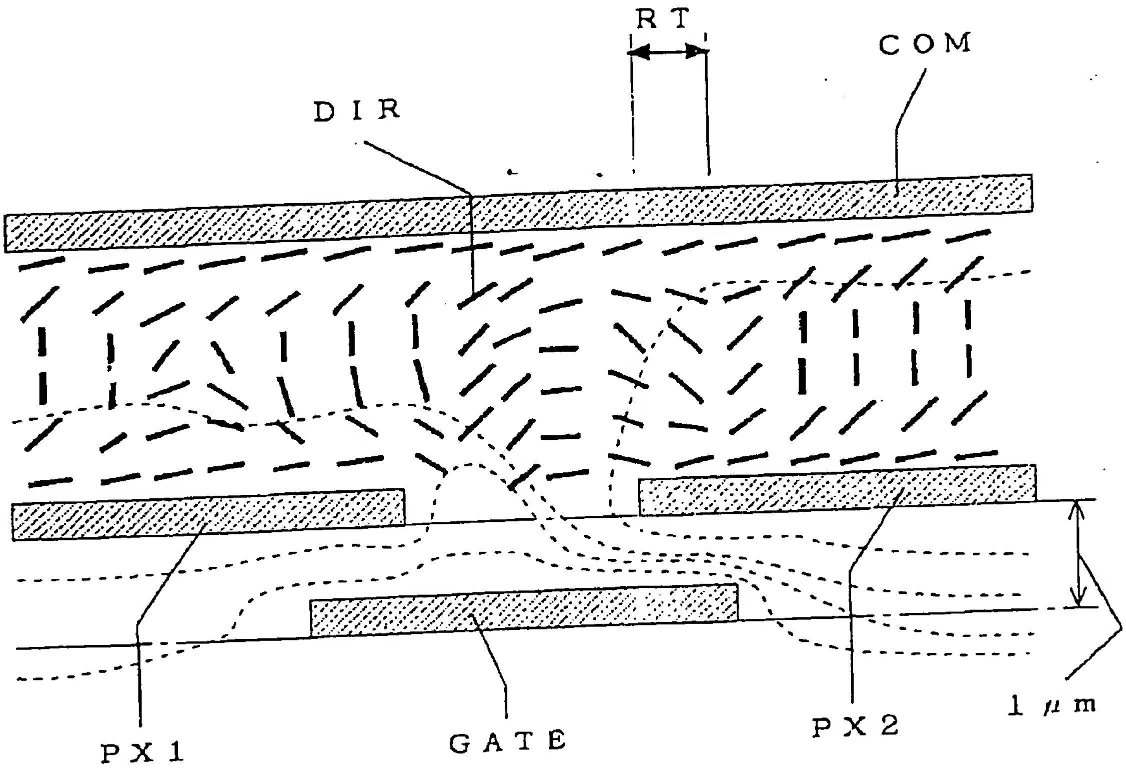
[Figure 1]



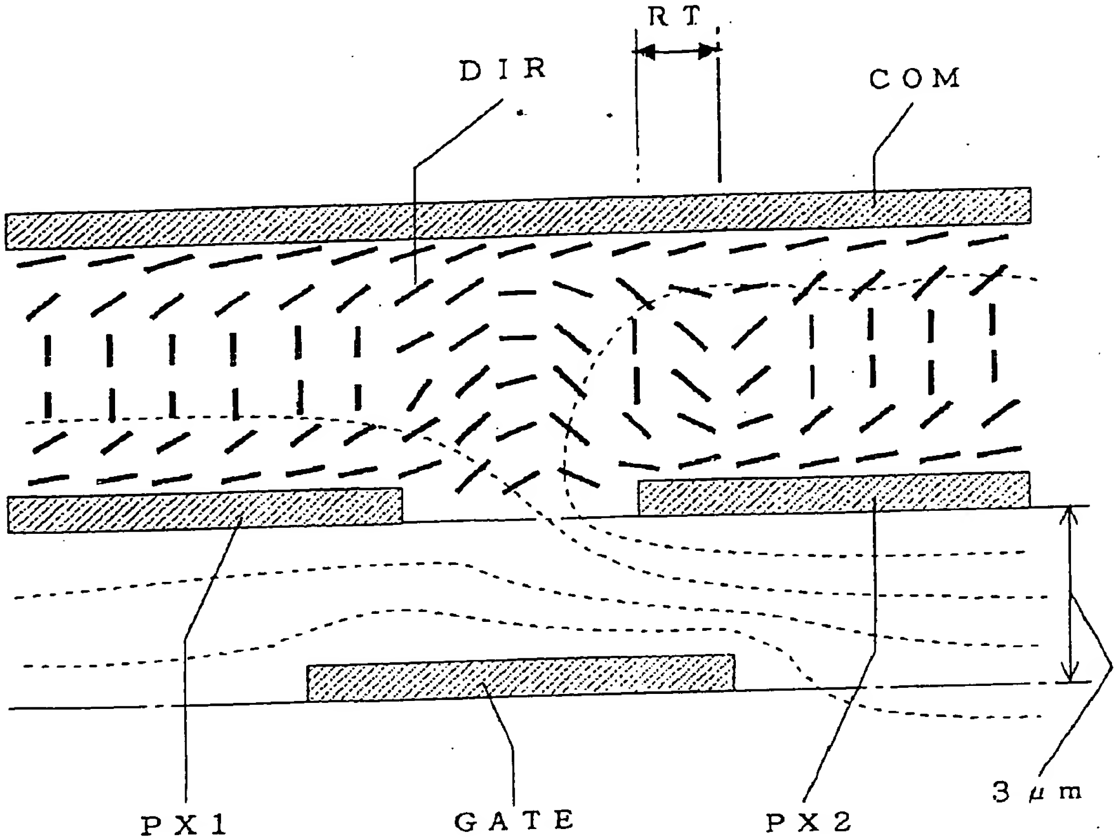
[Figure 2]



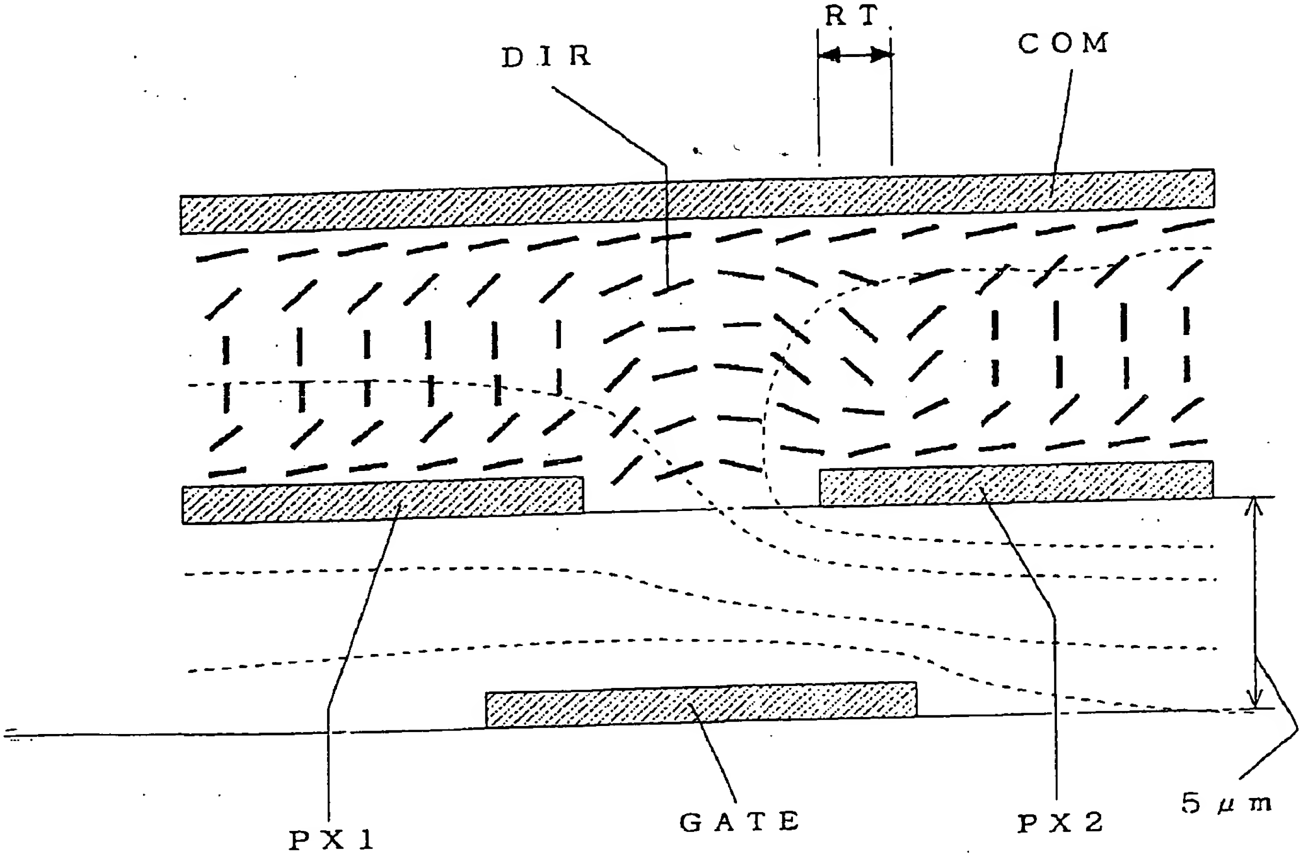
[Figure 3]



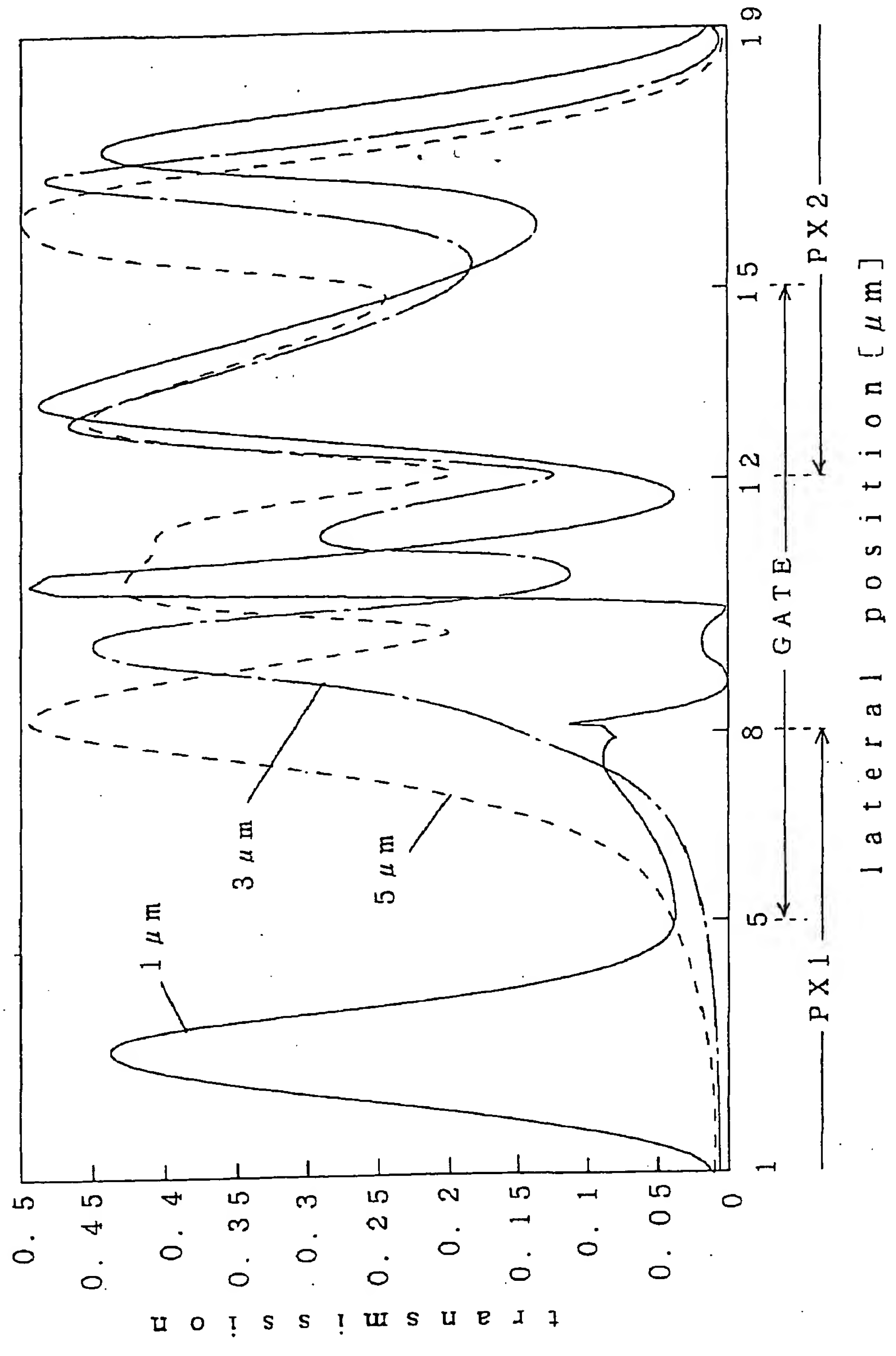
[Figure 4]



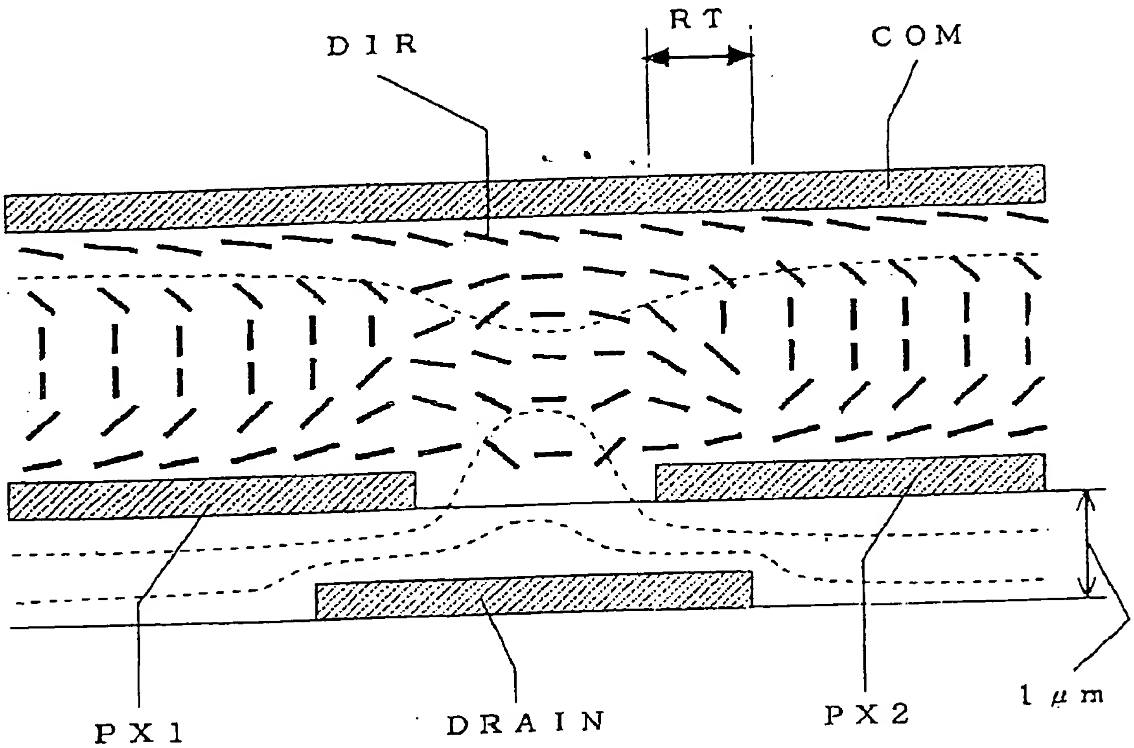
[Figure 5]



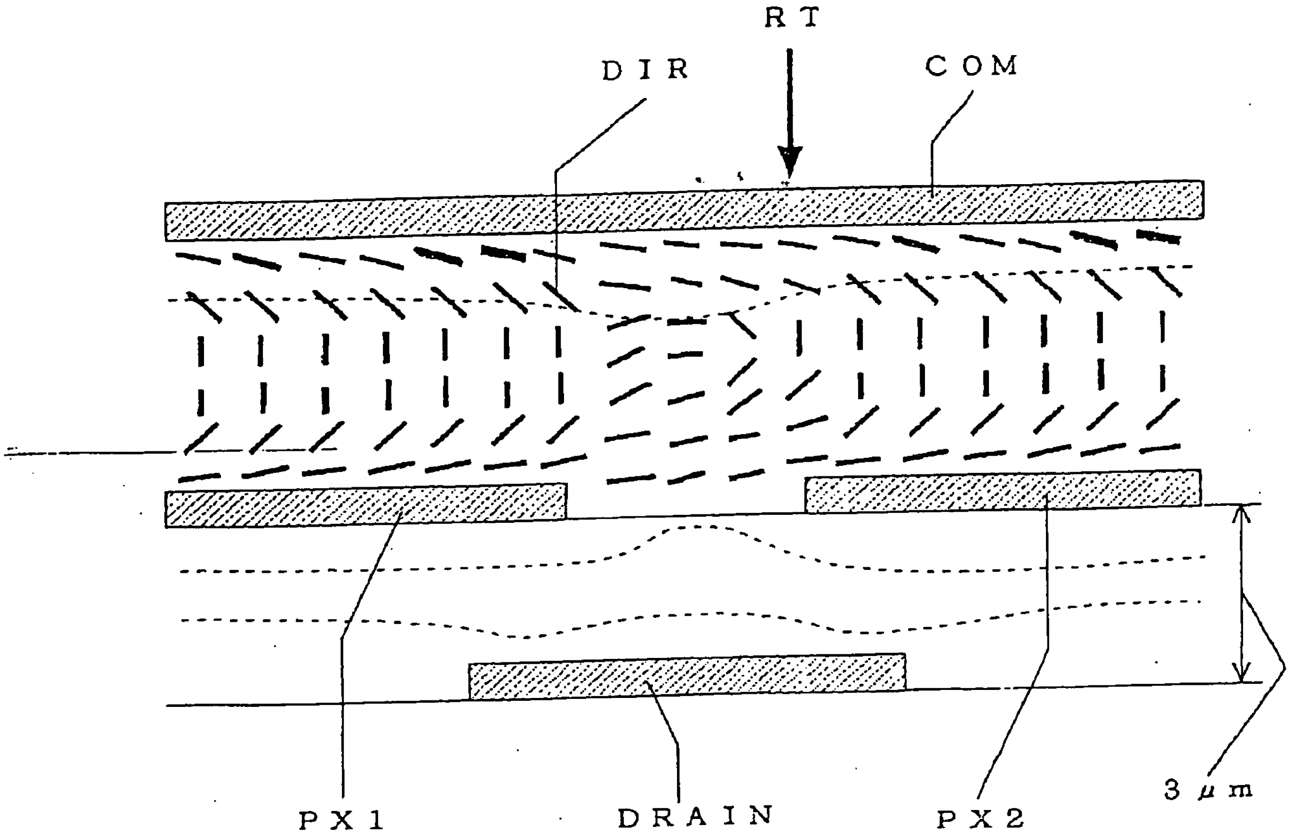
[Figure 6]


transmission
lateral position [μm]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
1
5
8
12
15
19
1μm
3μm
5μm
PX1
GATE
PX2

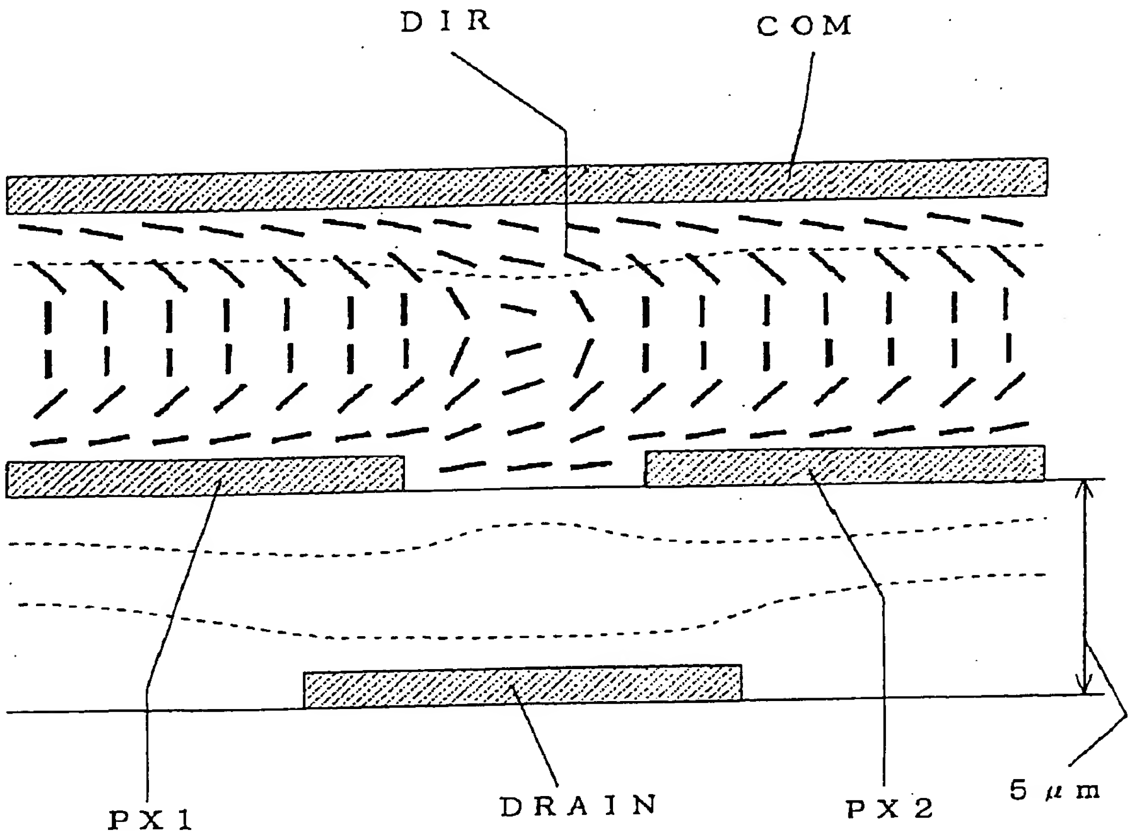
[Figure 7]



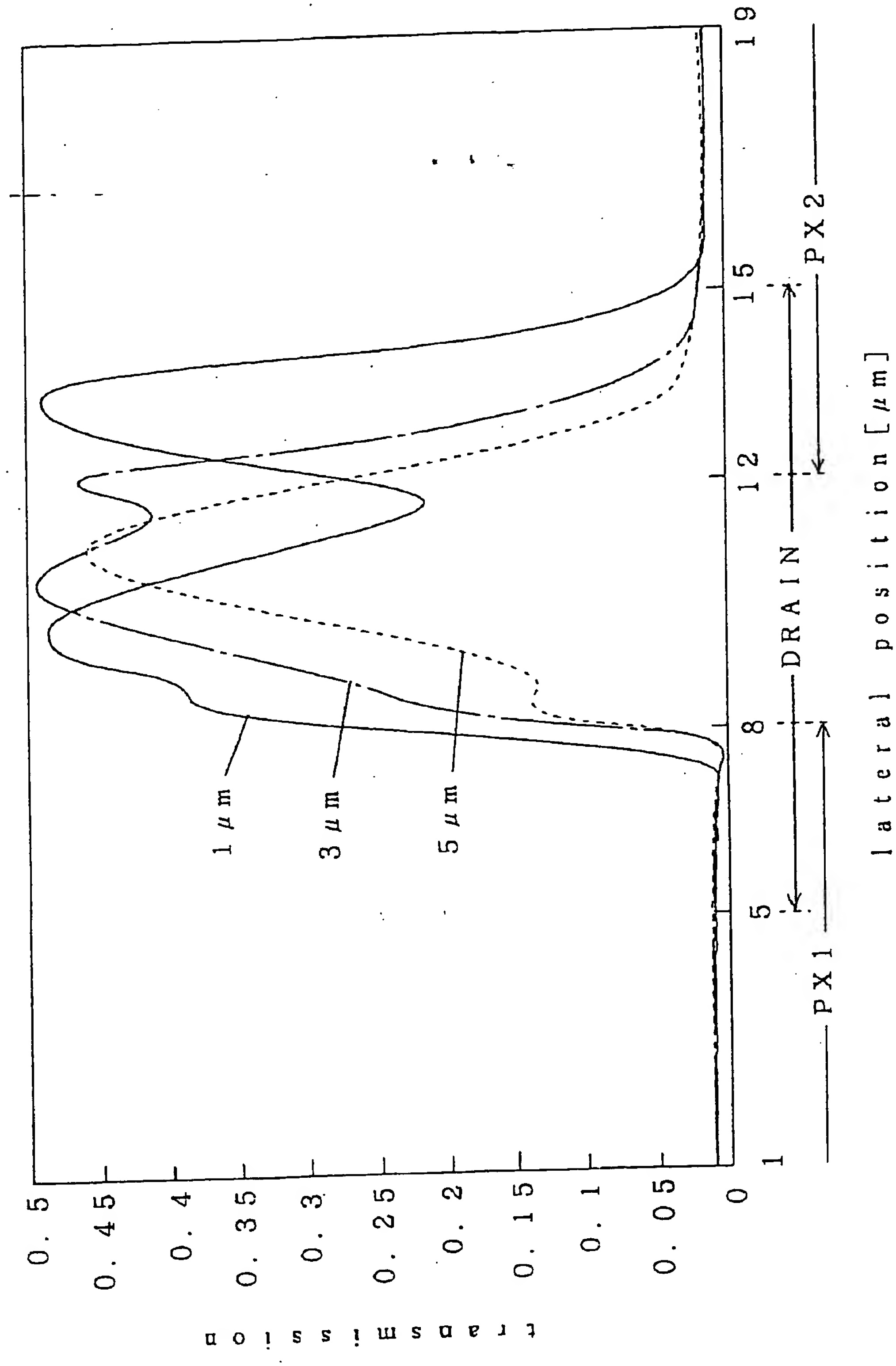
[Figure 8]



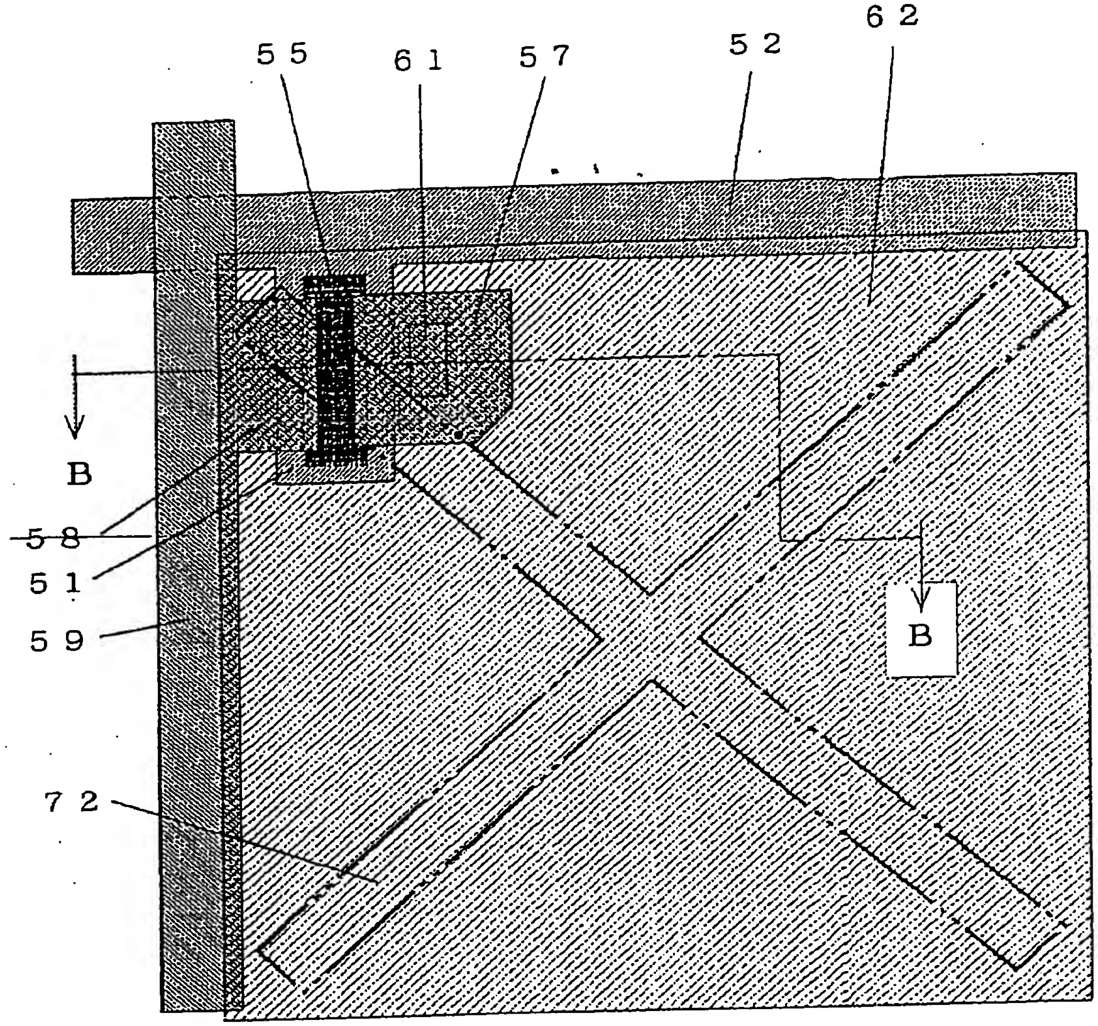
[Figure 9]



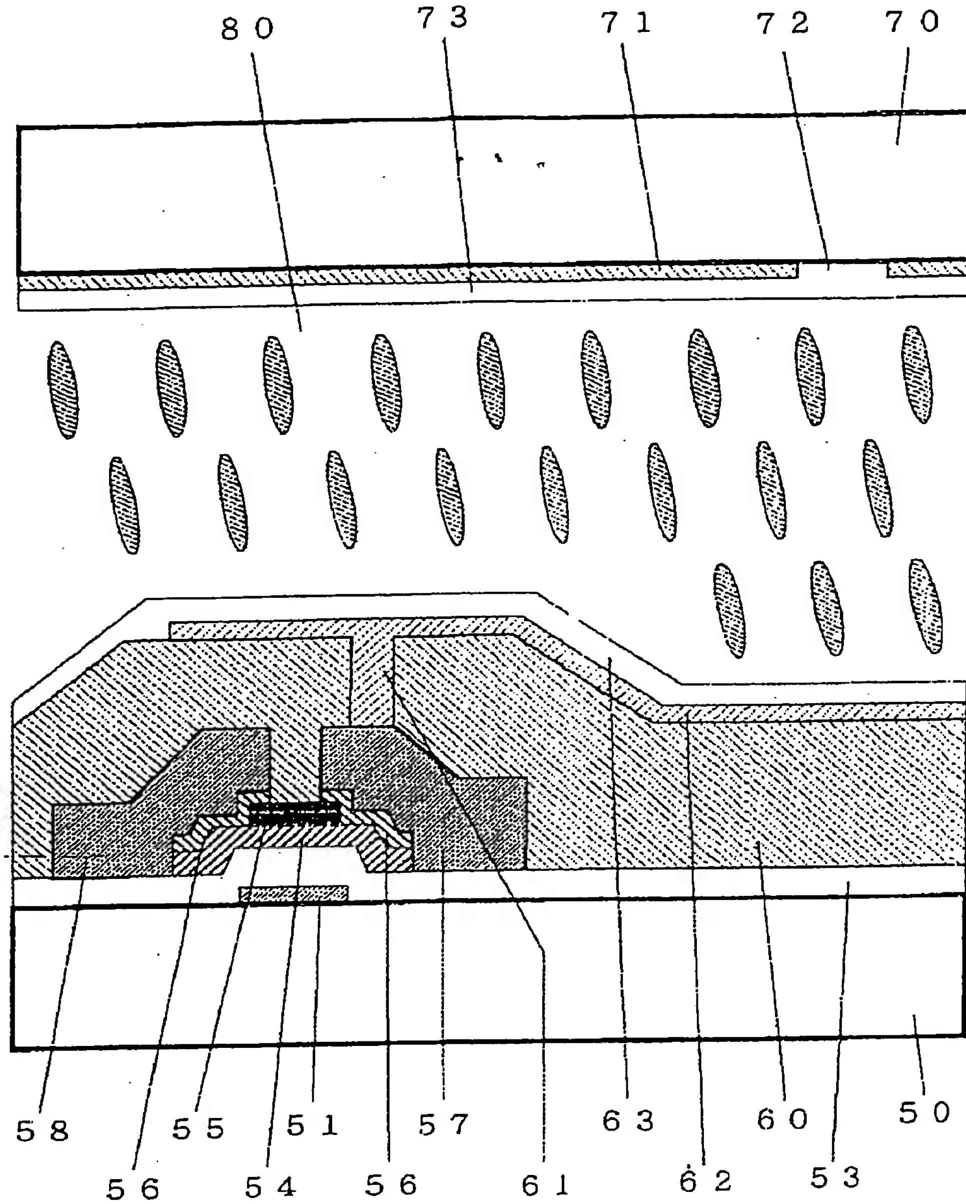
[Figure 10]


transmission
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
5
8
12
15
19
1 μm
3 μm
5 μm
PX1
DRAIN
PX2
lateral position [μm]

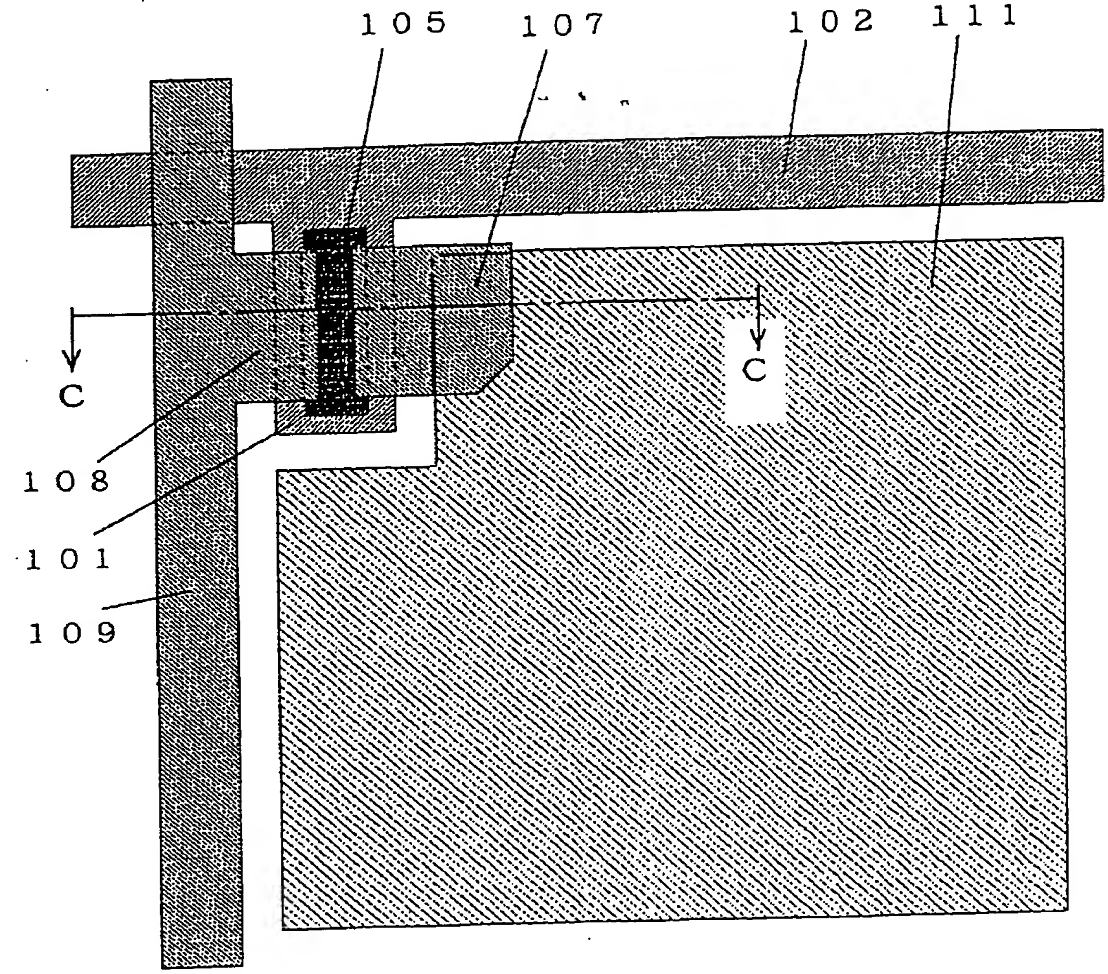
[Figure 11]



[Figure 12]



[Figure 13]



[Figure 14]